



Short term Size Deviation of Multivoltine, Multi x Bi and Bivoltine Raw Silk

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Abstract: Short term deviation of raw silk refers to the variation over a shorter magnitude of length. There are different kinds of raw silk viz., Multivoltine, Multi x Bi and Bivoltine. The present study aims at determining the short term size deviation over a shorter length of 20 metres. Unlike other textiles, the degree of non-uniformity or unevenness of raw silk is determined by some visual and visuo-mechanical tests which do not justly reflect the physical shape and size of the constituent fibre. The evenness variation in raw silk is greatly influenced by the type of cooking, type of reeling contrivances etc. and more importantly by the degree of variation in the size and shape of the constituent filament along the length being unravelled from the silk cocoon. The process parameters, type of machine are generally responsible for addition of irregularities in the yarn while the type of cocoon and type of silkworm varieties etc. are responsible for inherent irregularities. Though addition of irregularities can be controlled by using improved machineries and adopting proper process control measures, but the inherent irregularities in the yarn are genetically controlled..

Key words: Denier, Denier Deviation, Evenness, Co-efficient of Variation

I. Introduction

In sericultural advanced countries, raw silk is tested and graded according to specified and accepted standards before marketing [1]. This has been considered so important for the welfare of the silk industry that special institutions viz., silk conditioning and testing Houses (SCTH) have been established at a considerable expenditure. These are named so because they not only conduct quality tests but also find out the actual mercantile weight of raw silk. Desiccation or conditioning is necessary to prevent fraudulent transaction because silk is highly hygroscopic in nature. In order to assist the weaving industry, raw silk reeling industry requires well-defined standards, which can only be achieved by quality testing. As the demand for silk is global and a number of countries compete in the trade of raw silk, it is necessary to have some internationally accepted norms to enable a fair and equitable transaction of raw silk with transparency. This is the reason why all raw silk produced should be classified through testing [2]. According to Mahadevan et.al, 2011 [3], the important factor which have a direct bearing on productivity and quality of raw silk are the quality of raw material, process parameter, human skill, quality of water and reeling contrivance. He also observed that if the reeling speed is more than the optimum level, then the raw silk characteristics get affected. So for better and uniform quality production of raw silk, care should be taken right from the silkworm rearing till final product of raw silk.

Unlike other textiles, testing of raw silk is based on the some conservative procedures. The tests are being carried out according to the procedure laid down by the International Silk Association (ISA). The equipments used for testing of raw silk are of conventional type but earned a wide preference amongst silk producing and consuming countries in the world. The mechanical testing procedures of raw silk are almost similar everywhere, but the compilation of test results and standards for various grades differs slightly from country to country. In India, Bureau of Indian Standard's (BIS) norms are followed which is basically based upon the overall standards laid down by ISA. A proper assessment of the quality of silk assists the raw silk producer for decision making in regard to quality improvement by suitable manipulation in the related factors. Cocoon, the raw material for raw silk, being a bio-material, the occurrence of some natural variations is inevitable. Normally these variations in the silk cocoons are not visible in the raw silk filament by bare eye but whenever it is subjected for black board inspection, the size variation become prominent. This variation in the raw silk becomes more prominent at the fabric stage particularly with woven design and causes uneven dyeing particularly with lighter shade. So size deviation is a very important component for determining the ultimate quality of raw silk / fabric. There may be two types of size deviation, one as long term variation which may be the deviation over a comparatively longer length e.g., 100 metres or above and another is short term variation that refers to a shorter length e.g., 20 metres. The evenness variation test using seriplane winder generally describes the method of determining short term variation over a length of 20 metres or so. The present study is pointed towards finding out the size deviation of

raw silk over a length of 20 metres length and compares that with the evenness change degree measured through visuo-mechanical method. The evenness variation in raw silk is greatly influenced by the type of cooking, type of reeling contrivances etc. and more importantly by the degree of variation in the size and shape of the constituent filament along the length being unravelled from the cocoon surface. The process parameters, type of machine are generally responsible for addition of irregularities in the yarn while the type of cocoon and type of silkworm varieties etc. are responsible for inherent irregularities. Though addition of irregularities can be controlled by using improved machineries and by adopting proper process control measures, but the inherent irregularities in the yarn are genetically controlled. The study is focussed and restricted on the variation of linear density over the aforesaid sample length which is greatly influenced by the available filament length from a single cocoon and the skill of the operators as well.

II. Materials & Methods

In the present experimentation, raw silk of different voltinism viz., Multivoltine, Multi x Bi and Bivoltine were taken. Since there are huge varietal variation in terms of filament length and denier, all the three varieties have been taken to minimise the experimental error. Unlike other textiles, the degree of non-uniformity or unevenness of raw silk is determined by some visual and visuo-mechanical tests which do not reflect the objective analysis of physical shape, size and linear density of the resultant fibre in true sense. Irrespective of voltinism, silkworm *Bombyx mori* L produces raw silk bave of conical shape pointing towards pelade layer possibly due to gradual loss of concentration of aqueous protein solution resulting in decreasing shear rate at and above which silk fibroin crystallises to form fibre [4], which in turn, suggests that filament become more crystalline or ordered along its length with the advancement of spinning. According to Iizuka, 1983[5], some physical properties of *Bombyx mori* L are linearly related to the Size of thread. E. Iizuka et.al, 1993 [6] also studied that dynamic elastic modulus and tenacity show a negative correlation and the elongation, a positive correlation. So, the dry strength in terms of Tenacity (gms/denier) naturally increases as the fibre become more crystalline and similarly, elongation varies inversely with crystallinity. Variations in thickness of the individual filament influence the size or thickness of the resultant raw silk yarn. Hence, it is imperative to maintain the size deviation of individual filament within an acceptable range throughout its length. More the variation in individual filament more will be the non-uniformity in the resultant yarn. The decreased denier value may suggest the increased fineness of the silk filament [7]. The quality characteristics of raw silk viz., size deviation, winding break, tenacity and elongation % are strongly influenced by the variation of cocoon size in a given lot. Significant seasonal variation is also observed in reeling performance and yarn characteristics [8]. The skill of the reeler and other factors like quality of cocoons also happen to be the varying factor [9]. The variations in the yarn have direct bearing on mechanical properties of the resultant yarn, weaving performance and chemical response during wet processing. Therefore, size deviation is an important trait to decide the ultimate quality of raw silk. In the present study, the short term variation in the yarn has been assessed and compared with the evenness variation done separately by the visuo-mechanical evenness test which may throw some light on the evenness change degree along the length of the yarn.

The abbreviated codes of the cocoon varieties selected for the present study are:

- Multivoltine X Multivoltine (MxM), the cocoon with lower filament length and lower denier
- Multivoltine X Bivoltine (MxBi), the cocoon with intermittent filament length and denier
- Bivoltine X Bivoltine (Bi xBi), the cocoon with higher filament length and higher denier

The experiment has been designed to conduct the test with Raw silk produced from three breeds/hybrids of silkworm *Bombyx mori* L of different voltinism as mentioned earlier. Three hanks each of all the varieties of raw silk were taken and a total no. of 9 hanks have been prepared. Ten samples of equal length of 20 metres from each hank were prepared. 90 no. of such test samples @ 30 no. for each variety are made available for conducting the study. Thus total available length for testing was 1800 metres @ 600 metres for each variety. Standard Deviation of Size and Co-efficient of Variation was determined. Evenness variations by visuo-mechanical test were also carried out and compared. The equipments / apparatus used for the experimentation were Winding Machine, Epprouvete, Precision Electronic Balance, Seriplane Winder and Evenness Testing Apparatus. The raw silk samples were first unraveled in a winding machine to a 2-flanged bobbin at a winding speed of 120 metres per minute. The bobbins thus prepared were subjected to the metallic epprouvete having circumference of 1.25 metres for preparation of skein (hank) each having 20 metres length. From each hank 10 no. of samples were prepared and a total of 30 samples (from 3 hanks) were made ready from each variety of raw silk. From three varieties of raw silk a total no. of 90 samples were prepared. Size (denier) deviation test determine the degree of size variation within the test pieces of sizing skeins of definite length of raw silk. Size is the linear density i.e., the weight of 9000 meters filament in gram. Mathematically it is represented as:

Denier = $[W \div L \times 9000]$ Where, W = weight of filament (gms) and L =length of the filament (meters). Size Deviation can be determined by $(SD) = \sqrt{[\sum(x - \bar{x})^2] \div n}$ Where, x = Individual value of size, $\bar{x}$ = Average size n = No. of observation and Co-efficient of Variation (CV %) = $[SD \div \text{Mean}] \times 100$

III. Results and Discussions

The size or the thickness for filament yarn is expressed in 'denier' unit in direct system of yarn numbering. As raw silk consists of many numbers of individual filaments, the size variation occurs due to variation in thickness of individual filaments of the cocoon and variation in maintaining the equal no. of cocoons during reeling. So the linear density for each 20 metres fragment was calculated and the variations amongst the fragments were recorded. These variations are the size deviation from one fragment to others and have significant importance in deciding the quality of ultimate resultant raw silk / fabric. Minimum the variations minimum will be the size deviations and maximum will be the quality assurance. Table I, II & III show the denier deviations of multivoltine, multi x bi and bivoltine raw silk. To maintain reeling thread of the required size, the average cocoon no. per thread must be maintained to produce resultant silk thread of uniform size in all the ends during reeling. In advanced reeling machine, if the size of the yarn produced found different from the required size it is readjusted by the group size controller. This will ensure the uniformity by improving the accuracy of cocoon supply to each thread during reeling and thus minimise size deviation and evenness of raw silk greatly. But in traditional contrivances, the evenness or size deviation largely depends upon the human skill. Since traditional machines are generally high speed machine where the control mechanisms are also missing, the size variation naturally increases and the quality of the ultimate output deteriorates. Evenness variations are those defective portion of raw silk threads which show stripes caused by variation in the size of raw silk to such degree as is easily noticeable by visual inspection on an inspection board. The degree of such size variation of the raw silk thread is called intensity of variation. Standard are established for the purpose of determining the intensity of variation and are shown by the standard variation photographs. The evenness test gives an indication of sharp and erratic changes of size within a short length of raw silk filament by grasping the degree of these changes, which is very important. The weavers encounter processing problems when filament shows erratic changes in size along its length. The present study recorded an average short term size deviation of multivoltine raw silk as 1.66 and Co-Efficient of Variation as 6.80%. While comparing with the evenness variation, the same was recorded as 90.67 % i.e., both the observations are at par and has resemblance. Similar was the case for multi x bi and bi x bi raw silk where SD & CV % was recorded as 1.97 and 9.18% & 1.40 and 6.05 % respectively. The similar resemblances were found while comparing with the evenness degree recorded as 92.33 and 94.03% respectively for different varieties of raw silk. While analyzing the data it has been observed that lowest size deviation was found in Bivoltine raw silk. Naturally the coefficient of variation was lowest and evenness was highest in case of bivoltine raw silk. Other observations were made that multivoltine raw silk showed lower size deviation and lower coefficient of variation than that of multi x bi raw silk. But the evenness was found to be lower (90.67%) than multi x bi raw silk (92.33%). This observation appears to be little ambiguous and may be either due to poor quality raw material of multi x bi component or due to experimental error. However by and large, the findings of the experiment corroborate the findings of other works done in the same line previously. The tabular presentations of data for multivoltine, multi x bi and bivoltine raw silk are furnished below:

Bobbin-1		Race : M x M		Table-IA	
Sl. No.	Length (m)	Weight(g)	denier	SD	CV%
1	20	0.050	22.50	1.48	5.93
2	20	0.053	26.85		
3	20	0.054	24.30		
4	20	0.051	22.95		
5	20	0.056	25.20		
6	20	0.056	25.20		
7	20	0.055	24.75		
8	20	0.056	25.20		
9	20	0.060	27.00		
10	20	0.058	26.10		
Average		25.01			
Bobbin-2		Race : M x M		Table-IB	
Sl. No.	Length (m)	Weight (g)	denier	SD	CV%
1	20	0.054	24.30	1.80	7.34
2	20	0.055	24.75		
3	20	0.055	24.75		
4	20	0.056	25.20		
5	20	0.052	23.40		
6	20	0.058	26.10		
7	20	0.058	26.10		
8	20	0.059	26.55		
9	20	0.046	20.25		
10	20	0.054	24.30		
Average		24.57			
Bobbin-3		Race : M x M		Table-IC	
Sl. No.	Length (m)	Weight(g)	denier	SD	CV%
1	20	0.048	21.60	1.71	7.13
2	20	0.047	21.15		
3	20	0.053	23.85		
4	20	0.051	22.95		
5	20	0.057	25.65		
6	20	0.057	25.65		
7	20	0.056	25.20		
8	20	0.053	23.85		
9	20	0.054	24.30		
10	20	0.058	26.10		
Average		24.03			
Bobbin-1		Race : M x Bi		Table-IIA	
Sl. No.	Length (m)	Weight (g)	denier	SD	CV%
1	20	0.043	19.31	2.19	10.74
2	20	0.042	18.90		
3	20	0.041	18.45		
4	20	0.042	18.90		
5	20	0.041	18.45		
6	20	0.043	19.31		
7	20	0.047	20.65		
8	20	0.054	24.30		
9	20	0.053	23.85		
10	20	0.048	21.60		
Average		20.37			

Bobbin-2		Race : M x Bi		Table-IIB	
Sl. No.	Length (m)	Weight(g)	denier	SD	CV%
1	20	0.043	19.31	1.46	7.34
2	20	0.040	18.00		
3	20	0.039	17.55		
4	20	0.046	20.70		
5	20	0.048	21.60		
6	20	0.041	18.45		
7	20	0.047	21.15		
8	20	0.047	21.15		
9	20	0.045	20.50		
10	20	0.046	20.70		
Average		19.91			
Bobbin-3		Race : Mi x Bi		Table-IIC	
Sl. No.	Length (m)	Weight (g)	denier	SD	CV%
1	20	0.051	22.95	2.26	9.45
2	20	0.053	23.85		
3	20	0.056	25.20		
4	20	0.055	24.75		
5	20	0.056	25.20		
6	20	0.060	27.00		
7	20	0.046	20.70		
8	20	0.045	20.25		
9	20	0.051	22.95		
10	20	0.039	26.55		
Average		23.94			
Bobbin-1		Race : Bi x Bi		Table-IIIA	
Sl. No.	Length (m)	Weight(g)	denier	SD	CV%
1	20	0.046	20.70	1.47	6.45
2	20	0.045	20.25		
3	20	0.051	22.95		
4	20	0.048	21.60		
5	20	0.054	24.30		
6	20	0.051	22.95		
7	20	0.052	23.40		
8	20	0.053	23.85		
9	20	0.064	24.30		
10	20	0.053	23.85		
Average		22.82			
Bobbin-2		Race : Bi x Bi		Table-IIIB	
Sl. No.	Length (m)	Weight (g)	denier	SD	CV%
1	20	0.053	23.85	0.87	3.61
2	20	0.045	22.25		
3	20	0.054	24.30		
4	20	0.051	23.85		
5	20	0.052	23.40		
6	20	0.055	24.95		
7	20	0.055	24.75		
8	20	0.054	24.30		
9	20	0.065	24.75		
10	20	0.056	25.20		
Average		23.96			
Bobbin-3		Race : Bi x Bi		Table-IIIC	
Sl. No.	Length (m)	Weight(g)	denier	SD	CV%
1	20	0.048	21.60	1.85	8.09
2	20	0.053	23.85		
3	20	0.051	22.95		
4	20	0.055	24.75		
5	20	0.045	20.25		
6	20	0.044	19.80		
7	20	0.054	24.30		
8	20	0.050	22.50		
9	20	0.055	24.95		
10	20	0.054	24.30		
Average		22.93			
Bobbin-1		Multi x Multi		Table-IVA	
Sl. no	Intensity of variation	Width of strip (mm)	No. of strip	Evenness (%)	
1	V3/2	≤4 mm	1	93%	
2	V2	-do-	1	90%	
3	V2	-do-	1	90%	
4	V5/2	-do-	1	85%	
5	V3/2	-do-	1	93%	
6	V5/2	-do-	1	85%	
7	V3/2	-do-	1	93%	
8	V3/2	-do-	1	93%	
9	V3/2	-do-	1	93%	
10	V2	-do-	1	90%	
Average				90.5%	
Bobbin-2		Multi x Multi		Table-IVB	
Sl. no	Intensity of variation	Width of strip (mm)	No. of strip	Evenness (%)	
1	V3/2	≤4 mm	1	93	
2	V2	-do-	1	90	
3	V3/2	-do-	2	86	
4	V1	-do-	2	90	
5	V1	-do-	1	95	
6	V3/2	-do-	1	93	
7	V1	-do-	1	95	
8	V1	≤12 mm	1	90	
9	V3/2	-do-	1	93	
10	V2	-do-	1	90	
Average				91.5%	
Bobbin-3		Multi x Multi		Table-IVC	
Sl. no	Intensity of variation	Width of strip (mm)	No. of strip	Evenness (%)	
1	V3/2	≤4 mm	1	93%	
2	V2	-do-	1	90%	
3	V2	12mm	1	85%	
4	V1	≤4 mm	1	95%	
5	V3/2	≤12 mm	1	88%	
6	V1	≤4 mm	2	90%	
7	V3/2	-do-	1	93%	
8	V3/2	≤12 mm	1	88%	
9	V3/2	≤4 mm	1	93%	
10	V2	≤12 mm	1	85%	
Average				90%	

Bobbin-1					Multi x Bi				Table-VA
Sl. no	Intensity of variation	Width of strip (mm)	No. of strip	Evenness (%)					
1	V1	4 mm	1	95%					
2	V3/2	12 mm	1	88%					
3	V1/2	4 mm	1	97%					
4	V0	-do-	0	100%					
5	V2	-do-	1	90%					
6	V0	-do-	0	100%					
7	V1	-do-	1	95%					
8	V1	-do-	1	95%					
9	V2	-do-	1	90%					
10	V1	-do-	1	95%					
Average				94%					
Bobbin-2					Multi x Bi				Table-VB
Sl. no	Intensity of variation	Width of strip (mm)	No. of strip	Evenness (%)					
1	V1	≤4 mm	1	95%					
2	V2	≤12 mm	1	90%					
3	V1	≤4 mm	1	95%					
4	V3/2	-do-	1	93%					
5	V1	≤12 mm	1	88%					
6	V3/2	≤4 mm	2	90%					
7	V3/2	-do-	1	93%					
8	V3/2	-do-	1	93%					
9	V1	-do-	1	95%					
10	V3/2	-do-	1	93%					
Average				92%					
Bobbin-3					Multi x Bi				Table-VC
Sl. no	Intensity of variation	Width of strip (mm)	No. of strip	Evenness (%)					
1	V3/2	≤4 mm	1	93%					
2	V1	≤4 mm	1	95%					
3	V3/2	≤12 mm	1	88%					
4	V2	≤4 mm	1	90%					
5	V3/2	-do-	1	93%					
6	V1	-do-	2	90%					
7	V3/2	-do-	1	93%					
8	V3/2	≤12 mm	1	88%					
9	V1	≤4 mm	1	95%					
10	V3/2	-do-	1	93%					
Average				91.8%					
Bobbin-1					Bi x Bi				Table-VIA
Sl. no	Intensity of variation	Width of strip (mm)	No. of strip	Evenness (%)					
1	V2	≤4 mm	2	80%					
2	V0	-	-	100%					
3	V0	-	-	100%					
4	V1	≤4 mm	1	95%					
5	V2	≤12 mm	1	85%					
6	V0	-	-	100%					
7	V0	-	-	100%					
8	V0	-	-	100%					
9	V1	≤4 mm	1	95%					
10	V0	-do-	-	100%					
Average				95.5%					
Bobbin-2					Bi x Bi				Table-VIB
Sl. no	Intensity of variation	Width of strip (mm)	No. of strip	Evenness (%)					
1	V3/2	≤4 mm	1	93%					
2	V1	-do-	2	90%					
3	V3/2	≤12 mm	1	88%					
4	V3/2	≤4 mm	1	93%					
5	V1	-do-	1	95%					
6	V1/2	-do-	1	97%					
7	V1	-do-	2	90%					
8	V1	-do-	1	95%					
9	V1	-do-	1	95%					
10	V1/2	-do-	1	95%					
Average				93.1%					
Bobbin-3					Bi x Bi				Table-VIC
Sl. no	Intensity of variation	Width of strip (mm)	No. of strip	Evenness (%)					
1	V1	≤12 mm	1	88%					
2	V3/2	≤4 mm	1	93%					
3	V1	-do-	1	95%					
4	V1	-do-	2	90%					
5	V1	-do-	1	95%					
6	V1/2	-do-	1	97%					
7	V1	-do-	1	95%					
8	V1	≤12 mm	1	90%					
9	V1/2	-do-	1	97%					
10	V1	-do-	1	95%					
Average				95.5%					

Note: SD = Size Deviation; CV = Co-efficient of Variation

Av. Size deviation for multi X multi raw silk = 1.66; Av. Size deviation for multi X bi raw silk = 1.97

Av. Size deviation for bi X bi raw silk = 1.40; Av. Co-efficient variation multi X multi raw silk = 6.80%

IV. Conclusion

The important factors which have a direct bearing on productivity and quality of raw silk are the quality of raw material, process parameter, human skill, quality of water and reeling contrivances. Particularly uniformity characteristic like size deviation, maximum size deviation, evenness variation of raw silk are significantly influenced by raw material quality and reeling speed. Filament Length (FL) and Non-Breakable Filament Length (NBFL) seem to have wider role in deciding the uniformity of the yarn. Due to inferiority in raw

material quality, FL and NBFL are forced to be affected negatively which in turn play significant role in maintaining uniformity in the yarn. Because lower FL and NBFL means higher number of casting, but the casting efficiency of the reeler is limited. So when the raw material quality is inferior or reeling speed is higher the reeler has to work going beyond his or her optimum capacity which is impossible. This resulted in the production of a yarn with huge size deviation and higher co-efficient of variation. Since silk cocoon is a bio-material, there will be some inherent irregularities which cannot be removed. Unlike other textiles, silk therefore cannot be produced with almost zero-defect. However, a reeler should have that much of endeavour to produce yarn with a coefficient of variation below 5% that would help bringing Indian raw silk to the international standard.

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